

ASAE D497.4 MAR99
Agricultural Machinery Management Data



American Society of Agricultural Engineers

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Agricultural Machinery Management Data

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1 Purpose and scope

1.1 These data include representative values of farm machinery operation parameters as an aid to managers, planners, and designers in estimating the performance of field machines.

1.2 These data are intended for use with ASAE EP496. Some data are reported in equation form to permit use in computer and calculator mathematical models.

1.3 These data report typical values for tractor performance, implement power requirements, repair and maintenance costs, depreciation, fuel and oil use, reliability for field operation, probable working days, and timeliness coefficients as measured by experiment, modeling, or survey.

1.4 Where possible, variation in sampled data is reported using the range, a standard deviation, SD, or a coefficient of variation, CV, defined as SD/mean. In a normal distribution 68% of the population should be contained in a range of ± 1 SD about the mean, and 95% will be contained in a ± 2 SD.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Data. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Data are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Standards organizations maintain registers of currently valid standards.

ASAE S296.4 DEC95, *Terminology for Traction of Agricultural Tractors, Self-Propelled Implements and Traction and Transport Devices*

ASAE S313.2 DEC94, *Soil Cone Penetrometer*

ASAE S495 DEC94, *Uniform Terminology for Agricultural Machinery Management*

ASAE EP496.2 MAR94, *Agricultural Machinery Management*

3 Tractor performance

3.1 Drawbar performance of tractors depends primarily on engine power, weight distribution on drive wheels, type of hitch, and soil surface. Maximum tractive efficiency, TE , is optimized by compromising drive wheel slip, s , and motion resistance, MR . Figure 1 presents typical power relationships for agricultural tractors when properly ballasted for the desired operating speed. Tractive efficiency can be approximated by the ratio between PTO power and drawbar power. Four surface conditions and four types of tractors are included variables. The drive tire size is that just large enough to carry the expected dynamic loading.

3.2 Single-wheel performance equations for pneumatic tires are useful for design specifications, prediction of vehicle performance, and computer simulation of vehicle productivity. The following relationships apply to bias-ply tires on most agricultural, earthmoving, and forestry prime movers. The following equations are limited to tires with a b/d ratio

ranging from 0.1 to 0.7, statis radial tire deflections ranging from 10% to 30% of the undeflected tire section height, and W/bd values ranging from 15 to 55 kN/m².

3.2.1 Motion resistance, MR , (as defined in ASAE S296) is equal to the difference between gross traction, GT , and net traction, NT :

$$MR = GT - NT = W \left(\frac{1}{B_n} + 0.04 + \frac{0.5s}{\sqrt{B_n}} \right)$$

E

where:

$$B_n = \left(\frac{Clb}{W} \right) \left(\frac{1 + 5 \frac{\delta}{h}}{1 + 3 \frac{b}{d}} \right)$$

B_n is a dimensionless ratio;

W is the dynamic wheel load in force units normal to the soil surface, kN (lbf);

Cl is the cone index for the soil (see ASAE S313), kPa (lbf/in.²);

b is the unloaded tire section width, m (in.);

d is the unloaded overall tire diameter, m (in.);

h is the tire section height, m (in.);

δ is the tire deflection, m (in.);

s is slip (see ASAE S296), decimal.

3.2.1.1 Values of Cl and B_n for agricultural drive tires ($W/bd \cong 30$ kN/m²) on typical soil surfaces are:

| Soil | Cl (kPa) | B_n |
|-------------|------------|-------|
| Hard | 1800 | 80 |
| Firm | 1200 | 55 |
| Tilled | 900 | 40 |
| Soft, sandy | 450 | 20 |

These values are applicable to soils that are not highly compactible.

3.2.1.2 The motion resistance ratio, ρ , is a ratio of the motion resistance to dynamic wheel load.

$$\rho = \frac{MR}{W} = \frac{1}{B_n} + 0.04 + \frac{0.5s}{\sqrt{B_n}}$$

E

3.2.2 Net traction, NT (as defined in ASAE S296):

$$NT = W \left(0.88(1 - e^{-0.1 B_n})(1 - e^{-7.5 s}) - \frac{1}{B_n} - \frac{0.5s}{\sqrt{B_n}} \right)$$

where:

e is the base of natural logarithms.

3.2.3 Gross traction, GT (as defined in ASAE S296):

$$GT = W(0.88(1 - e^{-0.1 B_n})(1 - e^{-7.5 s}) + 0.04)$$

3.2.4 Tractive efficiency, TE :

$$TE = (1 - s) \frac{NT}{GT}$$

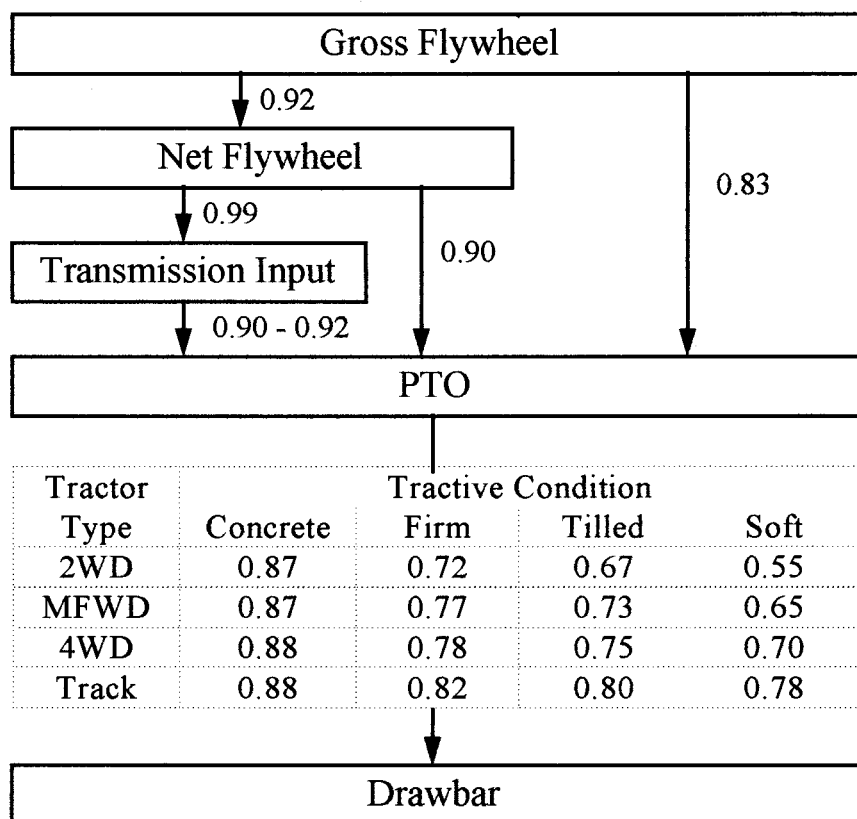


Figure 1 – Power relationships for agricultural tractors. Power at a given location in the drive train can be used to estimate power at another location. For example, PTO power can be estimated from net flywheel power by multiplying the net flywheel power by 0.90. If drawbar power is desired, choose the tractor type and tractive condition to determine the ratio. To estimate the drawbar power for a four-wheel drive tractor with 224 kW of net flywheel power operating on firm soil, multiply 224 by 0.90 and 0.78 to arrive at 157.25 kW.

3.3 Fuel efficiency varies by type of fuel and by percent load on the engine. Typical farm tractor and combine engines above 20% load are modeled by the equations below. Typical fuel consumption for a specific operation is given in L/kW-h (gal/hp-h) where X is the ratio of equivalent PTO power required by an operation to that maximum available from the PTO. These equations model fuel consumptions 15% higher than typical Nebraska Tractor Test performance to reflect loss of efficiency under field conditions. To determine the average fuel consumption of a tractor operating under a range of load conditions, over a period of time, refer to ASAE EP496.

Gasoline

$$2.74X + 3.15 - 0.203\sqrt{697X}$$

$$(0.54X + 0.62 - 0.04\sqrt{697X})$$

Diesel

$$2.64X + 3.91 - 0.203\sqrt{738X+173}$$

$$(0.52X + 0.77 - 0.04\sqrt{738X+173})$$

LPG (liquefied petroleum gas)

$$2.69X + 3.41 - 0.203\sqrt{646X}$$

$$0.53X + 0.62 - 0.04\sqrt{646X}$$

3.4 Oil consumption is defined as the volume per hour of engine crankcase oil replaced at the manufacturer's recommended change interval. Consumption is in L/h (gal/h), where P is the rated engine power in kW (hp).

Gasoline

$$0.000566P+0.02487 \quad (0.00011P+0.00657)$$

Diesel

$$0.00059P+0.02169 \quad (0.00021P+0.00573)$$

LPG (liquefied petroleum gas)

$$0.00041P+0.02 \quad (0.00008P+0.00755)$$

4 Draft and power requirements

4.1 Draft data are reported as the force required in the horizontal direction of travel. Both functional draft (soil and crop resistance) and

draft required to overcome rolling resistance of the implement are included with one exception: for manure injection, motion resistance of spreader transport wheels must be added to get total implement draft.

4.1.1 Draft force required to pull many seeding implements and minor tillage tools operated at shallow depths is primarily a function of the width of the implement and the speed at which it is pulled. For tillage tools operated at deeper depths, draft also depends upon soil texture, depth, and geometry of the tool. Typical draft requirements can be calculated as

$$D = F_i [A + B(S) + C(S)^2] WT$$

where:

- D is implement draft, N (lbf);
- F is a dimensionless soil texture adjustment parameter (table1);
- i = 1 for fine, 2 for medium and 3 for coarse textured soils;
- A , B and C are machine-specific parameters (table1);
- S is field speed, km/h (mile/h).
- W is machine width, m (ft) or number of fows or tools (table1);
- T is tillage depth, cm (in.) for major tools, 1 (dimensionless) for minor tillage tools and seeding implements.

Table 1 – Draft parameters and an expected range in drafts estimated by the model parameters for tillage and seeding implements

| Implement | SI Units | | | | English Units | | | | | | | Range ±% |
|---|----------------|--------------------|------|-----|----------------|--------------------|------|-----|-----------------|----------------|----------------|-------------|
| | Width units | Machine Parameters | | | Width units | Machine Parameters | | | Soil Parameters | | | |
| | | A | B | C | | A | B | C | F ₁ | F ₂ | F ₃ | |
| MAJOR TILLAGE TOOLS | | | | | | | | | | | | |
| Subsoiler/Manure Injector | | | | | | | | | | | | |
| narrow point | tools | 226 | 0.0 | 1.8 | tools | 129 | 0.0 | 2.7 | 1.0 | 0.70 | 0.45 | 50 |
| 30 cm winged point | tools | 294 | 0.0 | 2.4 | tools | 167 | 0.0 | 3.5 | 1.0 | 0.70 | 0.45 | 50 |
| Moldboard Plow | m | 652 | 0.0 | 5.1 | ft | 113 | 0.0 | 2.3 | 1.0 | 0.70 | 0.45 | 40 |
| Chisel Plow | | | | | | | | | | | | |
| 5 cm straight point | tools | 91 | 5.4 | 0.0 | tools | 52 | 4.9 | 0.0 | 1.0 | 0.85 | 0.65 | 50 |
| 7.5 cm shovel/35 cm sweep | tools | 107 | 6.3 | 0.0 | tools | 61 | 5.8 | 0.0 | 1.0 | 0.85 | 0.65 | 50 |
| 10 cm twisted shovel | tools | 123 | 7.3 | 0.0 | tools | 70 | 6.7 | 0.0 | 1.0 | 0.85 | 0.65 | 50 |
| Sweep Plow | | | | | | | | | | | | |
| primary tillage | m | 390 | 19.0 | 0.0 | ft | 68 | 5.2 | 0.0 | 1.0 | 0.85 | 0.65 | 45 |
| secondary tillage | m | 273 | 13.3 | 0.0 | ft | 48 | 3.7 | 0.0 | 1.0 | 0.85 | 0.65 | 35 |
| Disk Harrow, Tandem | | | | | | | | | | | | |
| primary tillage | m | 309 | 16.0 | 0.0 | ft | 53 | 4.6 | 0.0 | 1.0 | 0.88 | 0.78 | 50 |
| secondary tillage | m | 216 | 11.2 | 0.0 | ft | 37 | 3.2 | 0.0 | 1.0 | 0.88 | 0.78 | 30 |
| Disk Harrow, Offset | | | | | | | | | | | | |
| primary tillage | m | 364 | 18.8 | 0.0 | ft | 62 | 5.4 | 0.0 | 1.0 | 0.88 | 0.78 | 50 |
| secondary tillage | m | 254 | 13.2 | 0.0 | ft | 44 | 3.8 | 0.0 | 1.0 | 0.88 | 0.78 | 30 |
| Disk Gang, Single | | | | | | | | | | | | |
| primary tillage | m | 124 | 6.4 | 0.0 | ft | 21 | 1.8 | 0.0 | 1.0 | 0.88 | 0.78 | 25 |
| secondary tillage | m | 86 | 4.5 | 0.0 | ft | 15 | 1.3 | 0.0 | 1.0 | 0.88 | 0.78 | 20 |
| Coulters | | | | | | | | | | | | |
| smooth or ripple | tools | 55 | 2.7 | 0.0 | tools | 31 | 2.5 | 0.0 | 1.0 | 0.88 | 0.78 | 25 |
| bubble or flute | tools | 66 | 3.3 | 0.0 | tools | 37 | 3.0 | 0.0 | 1.0 | 0.88 | 0.78 | 25 |
| Field Cultivator | | | | | | | | | | | | |
| primary tillage | tools | 46 | 2.8 | 0.0 | tools | 26 | 2.5 | 0.0 | 1.0 | 0.85 | 0.65 | 30 |
| secondary tillage | tools | 32 | 1.9 | 0.0 | tools | 19 | 1.8 | 0.0 | 1.0 | 0.85 | 0.65 | 25 |
| Row Crop Cultivator | | | | | | | | | | | | |
| S-tine | rows | 140 | 7.0 | 0.0 | rows | 80 | 6.4 | 0.0 | 1.0 | 0.85 | 0.65 | 15 |
| C-shank | rows | 260 | 13.0 | 0.0 | rows | 148 | 11.9 | 0.0 | 1.0 | 0.85 | 0.65 | 15 |
| No-till | rows | 435 | 21.8 | 0.0 | rows | 248 | 19.9 | 0.0 | 1.0 | 0.85 | 0.65 | 20 |
| Rod Weeder | m | 210 | 10.7 | 0.0 | ft | 37 | 3.0 | 0.0 | 1.0 | 0.85 | 0.65 | 25 |
| Disk-Bedder | rows | 185 | 9.5 | 0.0 | rows | 106 | 8.7 | 0.0 | 1.0 | 0.88 | 0.78 | 40 |
| MINOR TILLAGE TOOLS | | | | | | | | | | | | |
| Rotary Hoe | m | 600 | 0.0 | 0.0 | ft | 41 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 30 |
| Coil Tine Harrow | m | 250 | 0.0 | 0.0 | ft | 17 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 20 |
| Spike Tooth Harrow | m | 600 | 0.0 | 0.0 | ft | 40 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 30 |
| Spring Tooth Harrow | m | 2,000 | 0.0 | 0.0 | ft | 135 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 35 |
| Roller Packer | m | 600 | 0.0 | 0.0 | ft | 40 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 50 |
| Roller Harrow | m | 2,600 | 0.0 | 0.0 | ft | 180 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 50 |
| Land Plane | m | 8,000 | 0.0 | 0.0 | ft | 550 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 45 |
| SEEDING IMPLEMENTS | | | | | | | | | | | | |
| Row Crop Planter, prepared seedbed | | | | | | | | | | | | |
| mounted | | | | | | | | | | | | |
| seeding only | rows | 500 | 0.0 | 0.0 | rows | 110 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 25 |
| drawn | | | | | | | | | | | | |
| seeding only | rows | 900 | 0.0 | 0.0 | rows | 200 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 25 |
| seed, fertilizer, herbicides | rows | 1,550 | 0.0 | 0.0 | rows | 350 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 25 |
| Row Crop Planter, no-till | | | | | | | | | | | | |
| seed, fertilizer, herbicides | | | | | | | | | | | | |
| 1 fluted coulter/row | rows | 1,820 | 0.0 | 0.0 | rows | 410 | 0.0 | 0.0 | 1.0 | 0.96 | 0.92 | 25 |
| Row Crop Planter, zone-till | | | | | | | | | | | | |
| seed, fertilizer, herbicides | | | | | | | | | | | | |
| 3 fluted coulters/row | rows | 3,400 | 0.0 | 0.0 | rows | 765 | 0.0 | 0.0 | 1.0 | 0.94 | 0.82 | 35 |
| Grain Drill w/press wheels | | | | | | | | | | | | |
| < 2.4 m drill width | rows | 400 | 0.0 | 0.0 | rows | 90 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 25 |
| 2.4 to 3.7 m drill width | rows | 300 | 0.0 | 0.0 | rows | 67 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 25 |
| > 3.7 m drill width | rows | 200 | 0.0 | 0.0 | rows | 25 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 25 |
| Grain Drill, no-till | | | | | | | | | | | | |
| 1 fluted coulter/row | rows | 720 | 0.0 | 0.0 | rows | 160 | 0.0 | 0.0 | 1.0 | 0.92 | 0.79 | 35 |
| Hoe Drill | | | | | | | | | | | | |
| primary tillage | m | 6,100 | 0.0 | 0.0 | ft | 420 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 50 |
| secondary tillage | m | 2,900 | 0.0 | 0.0 | ft | 200 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 50 |
| Pneumatic Drill | m | 3,700 | 0.0 | 0.0 | ft | 250 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 50 |

4.1.2 Typical, average draft requirement parameters are summarized in table 1 for most tillage and seeding machines. Each parameter is a function of tillage tool design. The constant parameter, *A*, is a function of soil strength while the coefficient of speed parameters, *B* or *C*, are related to soil bulk density. Soil is categorized as fine, medium, or coarse. Fine-textured soil is described as high in clay content, medium textured are loamy soils, and coarse textured are sandy soils. Typical values of all parameters are listed along with an expected range or variation due to differences in machine design, machine adjustment, machine age, and site-specific conditions including soil moisture and residue cover. This range gives the expected variation of average or typical draft as machine and soil conditions not included in the model vary.

4.2 Motion resistance is an additional draft force that must be included in computing implement power requirements. Values of motion resistance depend on transport wheel dimensions, tire pressure, soil type, and soil moisture. Soil moistures are assumed to be less than field capacity for implement operations. Motion resistance ratios are defined in ASAE S296 and predicted by 3.2.1.2.

4.2.1 The values given in 3.2.1 are for single wheels in undisturbed soil.

For loose, tilled soils and for sands, the motion resistance ratio for a rear wheel operating in the track of a front wheel is about 0.5 of the given value. For stubble ground the value is 0.9. For firm surfaces there is no reduction.

4.2.2 Extra width of flotation tires will reduce the coefficient appreciably on soft soils but will increase it for hard soils and concrete.

4.2.3 Motion resistance ratios increase with increased tire pressure in soft soils. Doubling the tire pressure to 200 kPa causes the coefficient to increase to $-0.0135 + 1.27X$ coefficient at 100 kPa (15 lbf/in.²).

4.2.4 An effective motion resistance ratio, ρ_e , can be computed for use on slopes:

$$\rho_e = \rho \cos \alpha \pm \sin \alpha$$

where:

ρ is the motion resistance ratio on level land (see 3.2.1.2);
 α is the slope. The minus sign is to be used for motion down slopes.

Table 2 – Rotary power requirement parameters

| Machine Type | Parameter | | | Parameter | | | Range ¹⁾ ±% |
|-----------------------------------|-----------|-----------|-------------------|-----------|------------|-------------------|---------------------------|
| | a kW | b kW/m | c kWh/t | a hp | b hp/ft | c hph/ton | |
| Baler, small rectangular | 2.0 | 0 | 1.0 ²⁾ | 2.7 | 0 | 1.2 ²⁾ | 35 |
| Baler, large rectangular bales | 4.0 | 0 | 1.3 | 5.4 | 0 | 1.6 | 35 |
| Baler, large round (var. chamber) | 4.0 | 0 | 1.1 | 5.4 | 0 | 1.3 | 50 |
| Baler, large round (fix. chamber) | 2.5 | 0 | 1.8 | 3.4 | 0 | 2.2 | 50 |
| Beet harvester ³⁾ | 0 | 4.2 | 0 | 0 | 1.7 | 0 | 50 |
| Beet topper | 0 | 7.3 | 0 | 0 | 3.0 | 0 | 30 |
| Combine, small grains | 20.0 | 0 | 3.6 ⁴⁾ | 26.8 | 0 | 4.4 ⁴⁾ | 50 |
| Combine, corn | 35.0 | 0 | 1.6 ⁴⁾ | 46.9 | 0 | 2.0 ⁴⁾ | 30 |
| Cotton picker | 0 | 9.3 | 0 | 0 | 3.8 | 0 | 20 |
| Cotton stripper | 0 | 1.9 | 0 | 0 | 0.8 | 0 | 20 |
| Feed mixer | 0 | 0 | 2.3 | 0 | 0 | 2.8 | 50 |
| Forage blower | 0 | 0 | 0.9 | 0 | 0 | 1.1 | 20 |
| Flail harvester, direct-cut | 10.0 | 0 | 1.1 | 13.4 | 0 | 1.3 | 40 |
| Forage harvester, corn silage | 6.0 | 0 | 3.3 ⁵⁾ | 8.0 | 0 | 4.0 ⁵⁾ | 40 |
| Forage harvester, wilted alfalfa | 6.0 | 0 | 4.0 ⁵⁾ | 8.0 | 0 | 4.9 ⁵⁾ | 40 |
| Forage harvester, direct-cut | 6.0 | 0 | 5.7 ⁵⁾ | 8.0 | 0 | 6.9 ⁵⁾ | 40 |
| Forage wagon | 0 | 0 | 0.3 | 0 | 0 | 0.3 | 40 |
| Grinder mixer | 0 | 0 | 4.0 | 0 | 0 | 4.9 | 50 |
| Manure spreader | 0 | 0 | 0.2 | 0 | 0 | 0.3 | 50 |
| Mower, cutterbar | 0 | 1.2 | 0 | 0 | 0.5 | 0 | 25 |
| Mower, disk | 0 | 5.0 | 0 | 0 | 2.0 | 0 | 30 |
| Mower, flail | 0 | 10.0 | 0 | 0 | 4.1 | 0 | 40 |
| Mower-conditioner, cutterbar | 0 | 4.5 | 0 | 0 | 1.8 | 0 | 30 |
| Mower-conditioner, disk | 0 | 8.0 | 0 | 0 | 3.3 | 0 | 30 |
| Potato harvester ³⁾ | 0 | 10.7 | 0 | 0 | 4.4 | 0 | 30 |
| Potato windrower | 0 | 5.1 | 0 | 0 | 2.1 | 0 | 30 |
| Rake, side delivery | 0 | 0.4 | 0 | 0 | 0.2 | 0 | 50 |
| Rake, rotary | 0 | 2.0 | 0 | 0 | 0.8 | 0 | 50 |
| Tedder | 0 | 1.5 | 0 | 0 | 0.6 | 0 | 50 |
| Tub grinder, straw | 5.0 | 0 | 8.4 | 6.7 | 0 | 10.2 | 50 |
| Tub grinder, alfalfa hay | 5.0 | 0 | 3.8 | 6.7 | 0 | 4.6 | 50 |
| Windrower/swather, small grain | 0 | 1.3 | 0 | 0 | 0.5 | 0 | 40 |

¹⁾Range in average power requirement due to differences in machine design, machine adjustment, and crop conditions.

²⁾Increase by 20% for straw.

³⁾Total power requirement must include a draft of 11.6 kN/m (±40%) for potato harvesters and 5.6 kN/m (±40%) for beet harvesters. A row spacing of 0.86 m for potatoes and 0.71 m for beets is assumed.

⁴⁾Based upon material-other-than-grain, MOG, throughput for small grains and grain throughput for corn. For a PTO driven machine, reduced parameter a by 10 kW.

⁵⁾Throughput is units of dry matter per hour with a 9 mm (0.35 in.) length of cut. At a specific throughput, a 50% reduction in the length of cut setting or the use of a recutter screen increases power 25%.

Table 3 – Field efficiency, field speed, and repair and maintenance cost parameters

| Machine | Field efficiency | | Field speed | | | | Estimated life | Total life R&M cost | Repair factors | |
|-------------------------------|------------------|-----------|-------------|-------------|------------|--------------|----------------|---------------------|----------------|-----|
| | Range % | Typical % | Range mph | Typical mph | Range km/h | Typical km/h | h | % of list price | RF1 | RF2 |
| TRACTORS | | | | | | | | | | |
| 2 wheel drive & stationary | | | | | | | 12 000 | 100 | 0.007 | 2.0 |
| 4 wheel drive & crawler | | | | | | | 16 000 | 80 | 0.003 | 2.0 |
| TILLAGE & PLANTING | | | | | | | | | | |
| Moldboard plow | 70–90 | 85 | 3.0–6.0 | 4.5 | 5.0–10.0 | 7.0 | 2 000 | 100 | 0.29 | 1.8 |
| Heavy-duty disk | 70–90 | 85 | 3.5–6.0 | 4.5 | 5.5–10.0 | 7.0 | 2 000 | 60 | 0.18 | 1.7 |
| Tandem disk harrow | 70–90 | 80 | 4.0–7.0 | 6.0 | 6.5–11.0 | 10.0 | 2 000 | 60 | 0.18 | 1.7 |
| (Coulter) chisel plow | 70–90 | 85 | 4.0–6.5 | 5.0 | 6.5–10.5 | 8.0 | 2 000 | 75 | 0.28 | 1.4 |
| Field cultivator | 70–90 | 85 | 5.0–8.0 | 7.0 | 8.0–13.0 | 11.0 | 2 000 | 70 | 0.27 | 1.4 |
| Spring tooth harrow | 70–90 | 85 | 5.0–8.0 | 7.0 | 8.0–13.0 | 11.0 | 2 000 | 70 | 0.27 | 1.4 |
| Roller-packer | 70–90 | 85 | 4.5–7.5 | 6.0 | 7.0–12.0 | 10.0 | 2 000 | 40 | 0.16 | 1.3 |
| Mulcher-packer | 70–90 | 80 | 4.0–7.0 | 5.0 | 6.5–11.0 | 8.0 | 2 000 | 40 | 0.16 | 1.3 |
| Rotary hoe | 70–85 | 80 | 8.0–14.0 | 12.0 | 13–22.5 | 19.0 | 2 000 | 60 | 0.23 | 1.4 |
| Row crop cultivator | 70–90 | 80 | 3.0–7.0 | 5.0 | 5.0–11.0 | 8.0 | 2 000 | 80 | 0.17 | 2.2 |
| Rotary tiller | 70–90 | 85 | 1.0–4.5 | 3.0 | 2.0–7.0 | 5.0 | 1 500 | 80 | 0.36 | 2.0 |
| Row crop planter | 50–75 | 65 | 4.0–7.0 | 5.5 | 6.5–11.0 | 9.0 | 1 500 | 75 | 0.32 | 2.1 |
| Grain drill | 55–80 | 70 | 4.0–7.0 | 5.0 | 6.5–11.0 | 8.0 | 1 500 | 75 | 0.32 | 2.1 |
| HARVESTING | | | | | | | | | | |
| Corn picker sheller | 60–75 | 65 | 2.0–4.0 | 2.5 | 3.0–6.5 | 4.0 | 2 000 | 70 | 0.14 | 2.3 |
| Combine | 60–75 | 65 | 2.0–5.0 | 3.0 | 3.0–6.5 | 5.0 | 2 000 | 60 | 0.12 | 2.3 |
| Combine (SP) ¹⁾ | 65–80 | 70 | 2.0–5.0 | 3.0 | 3.0–6.5 | 5.0 | 3 000 | 40 | 0.04 | 2.1 |
| Mower | 75–85 | 80 | 3.0–6.0 | 5.0 | 5.0–10.0 | 8.0 | 2 000 | 150 | 0.46 | 1.7 |
| Mower (rotary) | 75–90 | 80 | 5.0–12.0 | 7.0 | 8.0–19.0 | 11.0 | 2 000 | 175 | 0.44 | 2.0 |
| Mower-conditioner | 75–85 | 80 | 3.0–6.0 | 5.0 | 5.0–10.0 | 8.0 | 2 500 | 80 | 0.18 | 1.6 |
| Mower-conditioner (rotary) | 75–90 | 80 | 5.0–12.0 | 7.0 | 8.0–19.0 | 11.0 | 2 500 | 100 | 0.16 | 2.0 |
| Windrower (SP) | 70–85 | 80 | 3.0–8.0 | 5.0 | 5.0–13.0 | 8.0 | 3 000 | 55 | 0.06 | 2.0 |
| Side delivery rake | 70–90 | 80 | 4.0–8.0 | 6.0 | 6.5–13.0 | 10.0 | 2 500 | 60 | 0.17 | 1.4 |
| Rectangular baler | 60–85 | 75 | 2.5–6.0 | 4.0 | 4.0–10.0 | 6.5 | 2 000 | 80 | 0.23 | 1.8 |
| Large rectangular baler | 70–90 | 80 | 4.0–8.0 | 5.0 | 6.5–13.0 | 8.0 | 3 000 | 75 | 0.10 | 1.8 |
| Large round baler | 55–75 | 65 | 3.0–8.0 | 5.0 | 5.0–13.0 | 8.0 | 1 500 | 90 | 0.43 | 1.8 |
| Forage harvester | 60–85 | 70 | 1.5–5.0 | 3.0 | 2.5–8.0 | 5.0 | 2 500 | 65 | 0.15 | 1.6 |
| Forage harvester (SP) | 60–85 | 70 | 1.5–6.0 | 3.5 | 2.5–10.0 | 5.5 | 4 000 | 50 | 0.03 | 2.0 |
| Sugar beet harvester | 50–70 | 60 | 4.0–6.0 | 5.0 | 6.5–10.0 | 8.0 | 1 500 | 100 | 0.59 | 1.3 |
| Potato harvester | 55–70 | 60 | 1.5–4.0 | 2.5 | 2.5–6.5 | 4.0 | 2 500 | 70 | 0.19 | 1.4 |
| Cotton picker (SP) | 60–75 | 70 | 2.0–4.0 | 3.0 | 3.0–6.0 | 4.5 | 3 000 | 80 | 0.11 | 1.8 |
| MISCELLANEOUS | | | | | | | | | | |
| Fertilizer spreader | 60–80 | 70 | 5.0–10.0 | 7.0 | 8.0–16.0 | 11.0 | 1 200 | 80 | 0.63 | 1.3 |
| Boom-type sprayer | 50–80 | 65 | 3.0–7.0 | 6.5 | 5.0–11.5 | 10.5 | 1 500 | 70 | 0.41 | 1.3 |
| Air-carrier sprayer | 55–70 | 60 | 2.0–5.0 | 3.0 | 3.0–8.0 | 5.0 | 2 000 | 60 | 0.20 | 1.6 |
| Bean puller-windrower | 70–90 | 80 | 4.0–7.0 | 5.0 | 6.5–11.5 | 8.0 | 2 000 | 60 | 0.20 | 1.6 |
| Beet topper/stalk chopper | 70–90 | 80 | 4.0–7.0 | 5.0 | 6.5–11.5 | 8.0 | 1 200 | 35 | 0.28 | 1.4 |
| Forage blower | | | | | | | 1 500 | 45 | 0.22 | 1.8 |
| Forage wagon | | | | | | | 2 000 | 50 | 0.16 | 1.6 |
| Wagon | | | | | | | 3 000 | 80 | 0.19 | 1.3 |

¹⁾SP indicates self-propelled machine.

4.3 Rotary power data are reported as functional power required at the implement engine or tractor PTO shaft. Total power is determined by adding the rotary and draft power requirements to the power required to overcome motion resistance. Typical, average rotary power requirement parameters are summarized in table 2 for 32 major types of agricultural machines. The three parameters represent the no-load power requirement, the power requirement per unit of machine operating width and the power per unit of material feed rate. Draft requirements are also noted in table 2 for root harvesting machines. Typical values of all parameters are listed along with an expected range or variation due to

differences in machine design, machine condition and crop characteristics. Typical values can be adjusted within this range when conditions are likely to cause a substantial increase or decrease from the normal power requirement. Rotary power is determined using these parameters and the relationship defined in ASAE EP496, clause 4.1.2.

5 Machine performance

5.1 Performance rates for field machines depend upon achievable field speeds and upon the efficient use of time. Field speeds may be limited

by heavy yields, rough ground, and adequacy of operator control. Small or irregularly shaped fields, heavy yields, and high capacity machines may cause a substantial reduction in field efficiency. Typical speeds and field efficiencies are given in table 3.

5.2 Slippage of drive wheel, decimal, for ground-driven implements (see 3.2.3):

$$\text{Slippage (decimal)} = \frac{1}{0.3 C_n} \ln \left(\frac{0.75}{\frac{T}{rW} + \frac{1.2}{C_n} + 0.079} \right)$$

where:

- T is the torque due to mechanism operation on the drive wheel;
- r is the rolling radius of the drive wheel.

6 Costs of use

6.1 Depreciation costs are calculated using remaining value formulas estimated based on auction sale values of used farm equipment from 1984 to 1993. Calculate remaining value as a percentage of the list price for farm equipment at the end of n years of age and after h average hours of use per year using the following equation and the coefficients shown in Table 4.

$$RV_n = 100[C_1 - C_2(n^{0.5}) - C_3(h^{0.5})]^2$$

To include inflation effects, multiply the list price of farm equipment by $(1 + i)^n$ where i is the average annual inflation rate.

6.1.1 Remaining values as a percentage of the list price at the end of year n .

- E — tractors $68(0.920)^n$
- E — all combines, cotton pickers, SP windrowers $64(0.885)^n$
- E — balers, forage harvesters, blowers, and SP sprayers $56(0.885)^n$
- E — all other field machines $60(0.885)^n$

6.2 Repair and maintenance costs are highly variable and unpredictable as to time of occurrence. Surveys of accumulated repair and maintenance costs related to accumulated use do show consistent trends; however, a standard deviation equal to the mean is a typical

Table 4 – Remaining value coefficients

| Equipment type | C_1 | C_2 | C_3 |
|--|-------|-------|--------|
| Farm tractors | | | |
| Small <60 kW (80 hp) | 0.981 | 0.093 | 0.0058 |
| Medium 60–112 kW (80-150 hp) | 0.942 | 0.100 | 0.0008 |
| Large >112 kW (150 hp) | 0.976 | 0.119 | 0.0019 |
| Harvest equipment | | | |
| Combines | 1.132 | 0.165 | 0.0079 |
| Mowers | 0.756 | 0.067 | – |
| Balers | 0.852 | 0.101 | – |
| Swathers and all other harvest equipment | 0.791 | 0.091 | – |
| Tillage equipment | | | |
| Plows | 0.738 | 0.051 | – |
| Disks and all other tillage equipment | 0.891 | 0.110 | – |
| Miscellaneous equipment | | | |
| Skid-steer loaders and all other vehicles | 0.786 | 0.063 | 0.0033 |
| Planters | 0.883 | 0.078 | – |
| Manure spreaders and all other miscellaneous equipment | 0.943 | 0.111 | – |

variation in these data. Repair and maintenance factors based upon the accumulated use of the machine are given in table 3. Values listed are for machines used under typical field conditions and speeds. These data provide estimates of the average cost for all machines of a given type. The estimate is intended to be within 25% of the actual cost of maintaining most machines in good working order. Some machines may require considerably more or less repair than this estimate. A more complete description of the intended purpose and procedure for use of the data is given in ASAE EP496.

7 Reliability

7.1 Operational reliability is a probability of satisfactory machine function over any given time period. It is computed as one minus the probability of a failure.

7.1.1 Midwestern US reports by farmers (1970) of field failures show the probability of failure (tractors and implements combined) per 40 ha (100 acres) of use and the average SD of the total downtime per year for farms of over 200 ha (500 acres).

| | Breakdown time | | Breakdown probability per 40 ha | Reliability per 40 ha |
|----------------------|----------------|------|---------------------------------|-----------------------|
| | h/yr | SD | (100 acres) | (100 acres) |
| Tillage | 13.6 | 24.1 | 0.109 | 0.89 |
| Planting corn | 5.3 | 5.4 | 0.133 | 0.87 |
| Planting soybeans | 3.7 | 2.4 | 0.102 | 0.90 |
| Row cultivation | 5.6 | 6.3 | 0.045 | 0.96 |
| Harvest soybeans, SP | 8.2 | 9.6 | 0.363 | 0.64 |
| Harvest corn, SP | 12.3 | 12.6 | 0.323 | 0.68 |

7.1.2 Breakdown probabilities for machine systems increase with an increase in the size of the farm.

| Crop area, ha (acres) | Probability of at least one failure per year | Reliability of tractor-machine system per year |
|-------------------------|--|--|
| 0 to 80 (0 to 200) | 0.435 | 0.56 |
| 80 to 160 (200 to 400) | 0.632 | 0.30 |
| 160 to 240 (400 to 600) | 0.713 | 0.29 |
| 240+ (600+) | 0.780 | 0.22 |

7.1.3 Downtime and reliability appear to be independent of use for some machines while others have shown an increase with accumulated use. Midwestern US data show: Moldboard plows average 1 hour of downtime for each 400 ha (1000 acres) of use; row planters average 1 hour of downtime for each 250 ha (600 acres) of use; SP combines had little downtime for the first 365 ha (900 acres) of use. Downtime was a constant 1 hour for each 30 ha (70 acres) afterward; and tractors had a constantly increasing downtime rate with use. The accumulated hours of downtime depend upon the accumulated hours of use, X :

$$\begin{aligned} \text{Spark ignition} & 0.0000021 X^{1.9946} \\ \text{Diesel} & 0.0003234 X^{1.4173} \end{aligned}$$

8 Working days, timeliness

8.1 Freezing temperatures, precipitation, excessive deficient soil moistures, and other weather related factors may limit field machine operations. As weather variability is great, any prediction of the number of future working days can only be made probabilistically.

8.2 The number of working days in any time period is a function of: climatic region, slope of soil surface, soil type, drainage characteristics, operation to be performed, and traction and flotation devices.

Table 5 – Probabilities for a working day

| | Region | Central Illinois | State of Iowa | Southeastern Michigan | State of South Carolina | Southern Ontario Canada | Mississippi Delta |
|----------------------------|-----------------|---|---------------|---------------------------|--|--|--|
| | Soil | Prairie soils | State average | Clay loam | Clay loam | Clay loam | Clay |
| | Notes | 18 yr data | 17 yr data | | Simulation (tillage only) | Simulation (tillage only) | Simulation (tillage only) |
| | | In early spring and late fall, pwd in Iowa and Illinois may be 0.07 greater in North and West and 0.07 less in South and East | | Simulation (tillage only) | Sandy soils can be worked all months and have higher pwd | Start 7–10 days earlier on sandy soils, 0.15 greater pwd | Simulation (tillage only) Non-tillage field work pwd and pwd for sandy soils some greater in winter and early spring |
| Probability level, percent | | | | | | | |
| Average date | Biweekly period | 50 | 90 | 50 | 90 | 50 | 90 |
| Jan. and Feb. | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.01 | 0.0 |
| Mar. 7 | 1 | 0.0 | 0.0 | 0.0 | 0.0 | - | - |
| Mar. 21 | 2 | 0.29 | 0.0 | 0.0 | 0.0 | 0.03 | 0.0 |
| Apr. 4 | 3 | 0.42 | 0.13 | 0.39 | 0.16 | - | - |
| Apr. 18 | 4 | 0.47 | 0.19 | 0.57 | 0.38 | 0.29 | 0.06 |
| May 2 | 5 | 0.54 | 0.31 | 0.66 | 0.48 | - | - |
| May 16 | 6 | 0.61 | 0.34 | 0.68 | 0.47 | 0.61 | 0.32 |
| May 30 | 7 | 0.63 | 0.40 | 0.66 | 0.47 | - | - |
| June 13 | 8 | 0.66 | 0.41 | 0.69 | 0.52 | 0.72 | 0.48 |
| June 27 | 9 | 0.72 | 0.53 | 0.74 | 0.57 | - | - |
| July 11 | 10 | 0.72 | 0.52 | 0.77 | 0.64 | 0.67 | 0.43 |
| July 25 | 11 | 0.72 | 0.54 | 0.80 | 0.67 | - | - |
| Aug. 8 | 12 | 0.78 | 0.64 | 0.80 | 0.68 | 0.73 | 0.51 |
| Aug. 22 | 13 | 0.86 | 0.74 | 0.86 | 0.79 | - | - |
| Sept. 5 | 14 | 0.81 | 0.66 | 0.79 | 0.64 | - | - |
| Sept. 19 | 15 | 0.65 | 0.42 | 0.69 | 0.46 | 0.72 | 0.46 |
| Oct. 3 | 16 | 0.72 | 0.52 | 0.71 | 0.48 | - | - |
| Oct. 17 | 17 | 0.76 | 0.58 | 0.79 | 0.64 | 0.61 | 0.23 |
| Nov. 1 | 18 | 0.72 | 0.50 | 0.75 | 0.55 | - | - |
| Nov. 15 | 19 | 0.67 | 0.47 | 0.73 | 0.54 | 0.33 | 0.02 |
| Nov. 29 | 20 | 0.54 | 0.43 | 0.82 | 0.70 | - | - |
| Dec. 13 | 21 | - | - | - | - | 0.02 | 0.0 |

Adjust for Sundays and holidays by multiplying *pwd*'s above by 0.86, 0.82, 0.78, and 0.75 for months 0, 1, 2, and 3 holidays.

8.3 Probabilities for a working day, *pwd*, are given in table 5 for both 50% and 90% confidence levels. The probabilities obtained from the table are averages for biweekly periods. That is, a probability of 0.4 implies that 0.4×14 or 5.6 working days could be expected in that 2-week period. If the probability were taken at the 50% level, the 5.6-day figure would be exceeded in 5 years out of 10. If at the 90% level, the 5.6-day figure would be exceeded in 9 years out of 10.

8.3.1 Two types of field operations are identified soil working operations such as tillage and seeding and traffic operations where a crop is processed and the soil needs to be dry enough only to provide machine support. The Illinois and Iowa data in table 5 are reports of actual observed operations and include both types of operations. The other data are simulations for tillage operations only.

8.3.2 Dry western farms and farms under irrigation are likely to have a *pwd* approaching 1.0.

8.4 Persistence is recognized in weather data. Given that a particular day is a working day, the succeeding day has about a 0.8 (Midwest) probability of being a working day also. The probability of 5 consecutive working dates is the *pwd* for day 1 multiplied by $(0.8)^4$.

8.5 Timeliness considerations (see ASAE S495, clause 2) are important to efficient selection of farm machinery. An economic value for timeliness

is required to include the penalty for both quantity and quality reductions in the crop return from prolonged field machinery operations. Timeliness costs vary widely. Variation is expected among regions, crop varieties, time of the season, and machine operations. Timeliness costs are essentially zero for those tillage and other operations where there is little need to finish quickly.

8.6 A timeliness coefficient, *K* (see ASAE S495, clause 2), is a factor that permits computation of timeliness costs (see ASAE EP496, clause 8). This factor assumes linear timeliness costs with calendar days and is expressed as a decimal of maximum value of the crop per unit area per day either before or after the optimum day. These coefficients can be calculated from measured crop returns as they vary with the timing of machine operations. For example, if 10-day delay in an operation reduces the eventual return from the crop by 5%, *K* is calculated as $0.005/10$ or 0.005 per unit area per day. The cost of operating on 6 ha of \$100/ha crop by 7 days after the optimum would be $0.005 \times 6 \times 7 \times 100 = \21 . (For the timeless costs for harvesting a total field, see ASAE EP496, clause 8).

8.7 Values of *K* have been determined for several operations (Table 6).

Table 6 – K values, derived from crop research reports

| Operation | K |
|---|-------------|
| Tillage (depends on whether planting is delayed by prior tillage) | 0.000-0.010 |
| Seeding | |
| Corn | |
| Indiana, Illinois, Iowa, Eastern Nebraska, Eastern Kansas | |
| Available moisture in root zone at planting, cm | |
| 10 April 0.010 May 0.000 June —0.002 | |
| 20 April 0.006 May 0.001 June —0.003 | |
| 30 April 0.003 May 0.004 June —0.007 | |
| Wheat | |
| Utah | 0.008 |
| North Dakota | 0.007 |
| Soybeans | |
| Wisconsin, May & June | 0.005 |
| Missouri, Illinois, June | 0.006 |
| Double crop after wheat, Illinois | 0.010 |
| Cotton | |
| Lubbock, Texas | |
| April | 0.004 |
| May | 0.020 |
| Mississippi, April & May | 0.007 |
| Barley | |
| Utah | 0.008 |
| North Dakota | 0.007 |
| Oats | |
| Illinois & Michigan | 0.010 |
| Wisconsin, after May 6 | 0.012 |
| Alabama, Fall | 0.000 |
| Utah | 0.008 |
| Rape | |
| Manitoba | 0.003 |
| Rice | |
| California, May | 0.010 |
| Row cultivation | |
| Illinois, soybeans | 0.011 |
| Rotary hoeing | |
| Iowa, soybeans | 0.028 |
| Harvest | |
| Haymaking, Michigan, June | 0.018 |
| Shelled corn, Iowa | 0.003 |
| Ear corn, Illinois, after Oct. 26 | 0.007 |
| Soybeans, Illinois (depends on variety) | 0.006–0.010 |
| Wheat, Ohio | 0.005 |
| Cotton, Alabama | 0.002 |
| Rice, California | 0.009 |
| Sugar Cane, Queensland Australia | |
| preoptimum | 0.002 |
| postoptimum | 0.003 |